

THE
Indian Tea Association.

THE MANUFACTURE OF TEA
IN NORTH-EAST INDIA

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AND

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THE MANUFACTURE OF TEA IN NORTH-EAST INDIA

By

P. H. CARPENTER AND C. J. HARRISON.

The tea districts of North-east India, comprising as they do districts as widely different as Darjeeling and Upper Assam, Dooars and the Surma Valley, include almost every type of temperate and sub-tropical climate.

The soil too varies equally widely from district to district and includes sands, clays, peats and combinations of these types in almost every conceivable proportion. With two factors such as climate and soil varying to such an extent, it is easily understandable that, not only will the leaf plucked from the bushes vary in composition and quality, but that the general method of manufacture will be modified and varied from district to district and even from garden to garden. Other factors, such as the type of bush grown, the labour and the factory machinery available, exercise a profound influence on the methods for converting the raw material into the marketable product.

It will therefore be understood that until the abovenamed factors have been studied in relation to the changes taking place during manufacture, no definite rules governing the various processes in the factory can be formulated. It is the object of this monograph to indicate the progress made in our knowledge of the manufacturing process, and the extent to which the latter is influenced by climatic and other factors.

QUALITY OF GREEN LEAF.

It has been realised ever since the earliest days of tea, that many factors, both controllable and uncontrollable, affect the quality of the leaf on the bush.

It is well known that, other things being equal, the best tea is made from small, soft, slightly yellowish shoots consisting of a strict two leaves and bud, and plucked from bushes of

good type. On analysis, such leaf is found to contain, generally, the maximum of those substances which give rise to the desirable characteristics of a cup of tea.

The following table gives typical analyses of good and poor leaf.

					PERCENTAGE ON DRY MATTER.	
					Good leaf.	Poor leaf.
Tannin	...	...	...	...	25%	15%
Caffeine	...	...	...	...	4%	2%
Total soluble solids	...	...	...	...	47%	35%

The most important substances in the leaf are tannin, caffeine, aroma-producing substances and protein matter.

Tea tannin is regarded as most important, since it not only imparts the characteristic pungency, or astringency to tea liquor, but, during the manufacture, gives rise to the important red and brown colouring substances occurring in the final product. These substances will receive further attention in the paragraphs on manufacture. In addition, tannin is partly responsible for the effect known as "creaming down," which the liquor of some teas possess.

Tea tannin is so named on account of its chemical and physical resemblance to a group of bodies found in the bark and galls of oak, in mimosa, wattle and, in fact, many of the higher plants. Tannins, including tea-tannins, are white, amorphous substances easily soluble in water and solvents such as alcohol and acetic ether, and having a strongly astringent or pungent effect on the membrane of the mouth, and in particular on the gums.

Tannins have in addition certain distinctive chemical properties, of which the following are of importance:—

They form blue or green compounds with iron, these compounds being originally used as inks.

2. They have the power of combining with the gelatine in skins and hides, producing a hard, rubbery substance. This effect is known as the tanning of skins, and results in the leather of commerce.
3. In neutral or alkaline solution, they are rapidly oxidised by air to give brown, tasteless substances.
4. Many of them produce, in acid solution, red insoluble substances known as phlobaphenes, or "tannin-reds."
5. They are all slightly acidic in character.

As is generally the case, tea tannin does not occur free in the plant tissue, but is combined with another substance, the nature of which is not yet understood. This tannin complex has none of the astringent properties of free tannin, but is bitter.

It is only after plucking that the tannin compound is split up and astringent tannin is released.

Normally a tea shoot contains about 77 per cent. of water and of the remaining 23 per cent. of dry matter about one-fifth is tannin. The latter is, however, variable and is influenced by climate, soil and the different treatments which the tea bush receives at the hands of the cultivator.

About 5 per cent. of the solid matter in a normal tea shoot is caffeine, a white crystalline substance, having a slightly bitter taste and a stimulating effect on the system.

Tea is consumed mainly on account of its caffeine. Caffeine is colourless, odourless, and practically tasteless, and has no influence on the colour or smell either of the dry tea or the liquor, but has been found to have considerable influence on the quality of the tea as measured by its market price.

During withering, rolling and fermenting, no caffeine is lost, except when, by hard rolling, leaf juice is expelled, and even then the loss is very small. During firing, however, considerable loss of caffeine may occur. Caffeine is a substance

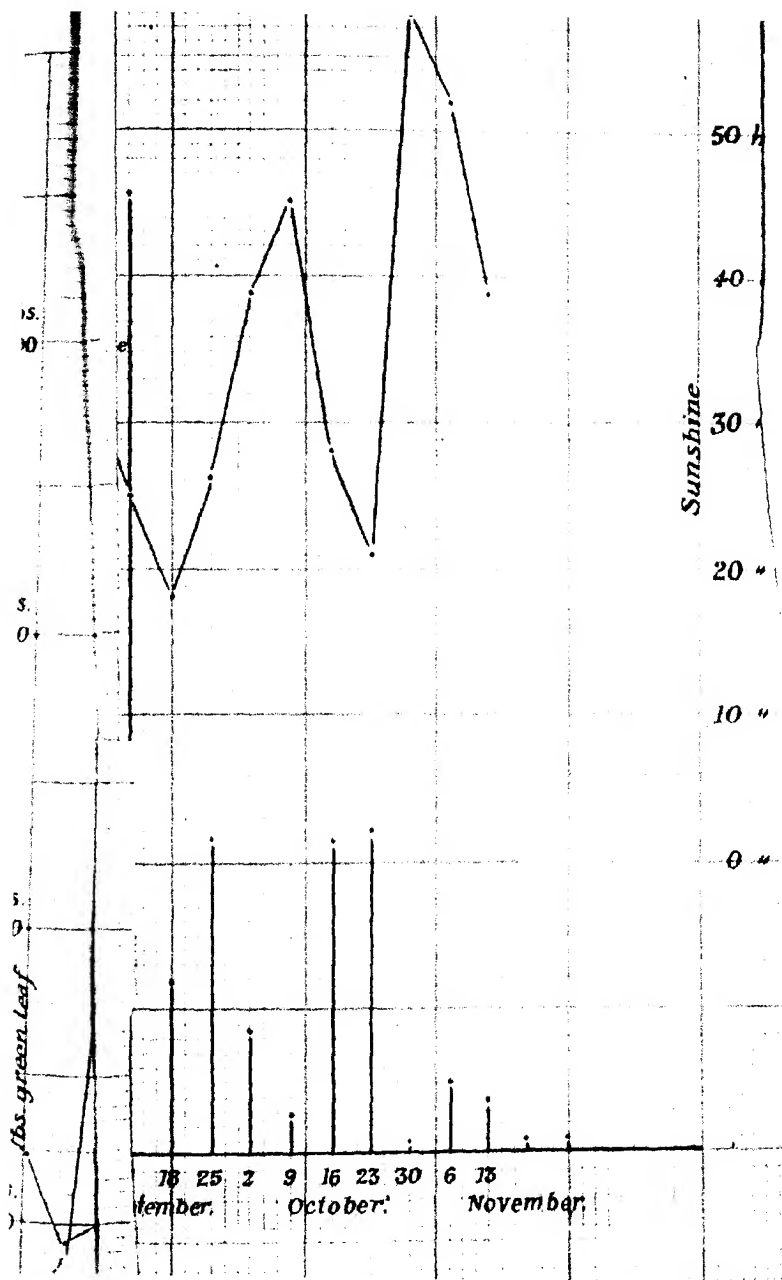
which, on heating, disappears as a vapour and settles out as a solid on cool surfaces. At ordinary firing temperatures some caffeine is certainly lost, but this loss may be reduced to a minimum by low temperature firing. So far, analyses show that the best teas contain higher percentages of caffeine than the poorer teas, the variation being usually between 2 per cent. and 4 per cent.

Little analytical work has so far been carried out on the question of flavour, since the quantities of substance concerned are very minute. It appears, however, to be a question of chemical changes taking place during the process of fermentation. No method of analysis has so far been devised for indicating the character of flavour in teas.

Complex nitrogenous bodies such as occur in all plants are extracted in a tea infusion and constitute the food value of a cup of tea. The amount of protein present probably influences the body or thickness of liquor, but though in Japan considerable weight is attached to protein analyses these are not considered to be of primary importance in India.

The difficulty in correlating changes in the climate with the tannin content of the leaf is, that we are at present uncertain as to the length of time which elapses before a particular set of climatic conditions takes effect on the bush. If we assume that variation in rate of growth, as indicated by the crop curve, is coincident with tannin changes in the leaf, and that variation in the rate of growth is dependent on weather variation, we can then attempt the correlation of weather conditions with tannin content (See Curve opposite). Even then, the occurrence of periodic flushes, indicated by peaks in the crop curves, hinders correlation to some extent.

The tannin content of the leaf rises irregularly from March to September and then drops as the season closes. A combination of weather conditions, such as high humidity and



hot, fairly sunny days, which induces sudden rapid growth, at the same time lowers the tannin content of the leaf and also the total soluble solid content.

Cool weather, during which growth is slowed up, results in an increase in tannin content and general improvement in quality, although, if as often happens, these conditions are accompanied by cloudy skies, the effect of the shade is to lower the tannin content. This introduces the effect of shade on the quality of tea.

Generally speaking, heavy shade has an adverse effect on quality of tea. The results of an experiment on an Assam tea garden are worthy of note in this connection.

Effect of shade.

The tea used for experiment had been planted in 1917, and at the same time, one-year old Sau-trees were put in at 30 feet by 30 feet apart. At the end of 1922 an area of, to all appearance, very even tea, was divided into three blocks treated as follows. All other treatment was the same for all blocks.

On No. 1 Block.—Sau trees were left as planted, i.e., 30 feet by 30 feet apart.

On No. 2 Block.—Sau trees were thinned out so as to remain 30 feet by 60 feet apart.

On No. 3 Block.—All shade trees were cut out.

Monthly reports on the teas made gave a decided preference on the whole to the more lightly shaded area (No. 2 Block) in 1923, the unshaded block being a fairly steady second.

In 1924 each report was to the effect that there was "very little in it" between the three samples but No. 3 (no shade) received decided preference in July and December, and No. 1 (full shade) in October, when No. 3 was picked out for briskness, but was found without colour and substance. In 1925, No. 3 (no shade) easily led in July, August and September, but was again reported on in October as being light and thin. No. 2 (medium shade) generally held second place, but was placed first in June.

The 1925 reports are probably the most significant since the bushes had had three years of different treatment.

On the whole the quality appears to be lost by the presence of heavy shade. Tea from unshaded bushes was frequently referred to as "light," but briskness, pungency, tip and occasional flavour are more often associated with unshaded tea. The preference given to unshaded tea is most marked during the rains, when tea under shade grows vigorously with perhaps a tendency to rankness. At the end of the season unshaded tea is generally less liked. There is no doubt that the excessive sunshine at this time of the year exercises a definitely harmful effect, not only so far as the type of leaf plucked is concerned, but on the substances in the leaf.

Hope showed that there is a direct connection between the amount of light falling on the leaf and the quality of the extract prepared from it. In this case the extracts were made under conditions approximating to the preparation of tea for drinking purposes and were analysed for tannin and total solids. Several bushes were shaded by thatch such that half received natural sunshine, and the other half remained in heavy shade and never received direct sunlight. After a few days the shaded leaves became darker green, more shining, and the stalks were noticeably drawn out.

Analyses of the extracts gave :—

				Total Solids.	Tannin.
1.	In exposure	...	...	10.5	2.81
	In shade	...	...	11.0	2.76
2.	In exposure	...	...	8.0	1.96
	In shade	...	...	9.0	1.70
3.	In exposure	...	...	9.4	2.44
	In shade	...	...	10.0	2.14
4.	In exposure	...	...	10.8	2.36
	In shade	...	...	11.0	2.11

While the total soluble matter is increased by the shading, the tannin is noticeably reduced.

Similar differences were obtained when bushes of the same type away from, and under Sau trees, were compared.

				Total Solids.	Tannin.
1.	Away from Sau trees	...	...	10.1	1.75
	Under Sau trees	...	...	11.1	1.44
2.	Away from Sau trees	...	...	10.2	1.39
	Under Sau trees	...	...	10.0	1.24
3.	Away from Sau trees	...	...	10.4	2.28
	Under Sau trees	...	...	10.0	2.00

Shade therefore reduces the tannin content of tea. This fact is made use of in the production of green teas in Japan (where green teas are better liked if they show little pungency). Teas of very high value are produced by shading part of the garden with cloth.

The shading also improves the colour, a great point in a green tea. When black teas of good quality are desired it is clear that some care must be exercised in the use of shade trees. While benefiting the health of the bush when used in moderation, too heavy shade will lead to loss of quality.

Apart from actual shade, lack of sunshine due to clouds was shown to have a similar effect on the tannin content of the leaf. In dull, overcast weather teas lacking in pungency are produced.

The general conclusion is therefore that, at the beginning and end of the season, when sunshine is strong and unmitigated by rainfall, lack of shade produces thinner but more pungent teas.

During the rains however, the benefit of shade is less marked when the sky is cloudy.

No close correlation between the type of soil and quality has yet been obtained. There are instances of gardens on exactly the same type of soil producing teas of widely different quality. It is generally accepted that tea from bheel gardens is poorer than that from

sandier and less rich soils. This is a matter more of the rate of growth of the shoot than of any inherent property of the soil itself, though the deficiency of potash in such soils may have some connection with the quality of the leaf.

No definite information on the question of the connection between type of bush and quality is available, and any generalisations made must always be qualified by notable exceptions. Usually, however, under similar conditions of growth, light leaved shoots contain a little more tannin than dark leaved. This is shown in the table on page 8.

There is no evidence to show that the application of suitable manures in quantities as at present applied has any ill effect on the quality of the tea.

Unduly large applications of quick-acting nitrogenous manures, particularly when applied without potash and phosphatic manures, may affect the quality adversely.

It is clear that any falling-off in the quality of recent years is due not to the increased use of manures, to revised methods of cultivation, or to adverse climatic conditions, but rather to the fact that labour generally is less plentiful, while crops have increased and machinery is in many cases inadequate and unsuitable.

Leaf plucked above a long length of old wood is of better quality than leaf plucked above a shorter length of old wood.

Below are given tannin and moisture figures averaged from analyses made throughout the season, showing how the quality of the leaf is affected by pruning. In each pair of examples the length of new wood was the same.

Height of pruning.	Percentage of tannin on dry leaf.	Percentage of moisture.
18"	23.65%	76.2%
12"	22.09%	76.0%
16"	21.20%	76.5%
6"	19.65%	76.1%

The highest tannin percentage is obtained from shoots of unpruned tea, where the moisture is correspondingly lower.

		Tannin % on dry leaf.	Moisture %.
Unpruned	...	24.16	75.2
Medium pruned	...	23.65	76.4
Heavy pruned	...	22.67	77.1

The table below compares the tannin content of the various parts of shoots from low and high pruned tea of light and dark leaf varieties.

			% Tannin on the dry leaf.	
			Light leaf.	Dark leaf.
Bud	low pruned	...	25 %	23.5 %
	high pruned	...	26 %	25 %
First leaf	low pruned	...	26 %	25 %
	high pruned	...	26.5 %	26 %
Second leaf	low pruned	...	20.5 %	20 %
	high pruned	...	22.5 %	26 %
Stalk	low pruned	...	11 %	10.5 %
	high pruned	...	12 %	11.5 %

In every case the percentage of tannin is higher in the component parts of shoots plucked from the longer growth of old wood.

Plucking affects the quality of the leaf in two ways. Firstly, the lighter the plucking, that is, the longer the length of new wood left, the poorer is the quality of the leaf. The following figures illustrate this.

Length of new wood.	Percentage tannin on dry leaf.	Percentage moisture.
6"	21.8 %	76.6 %
18"	19.8 %	77.1 %
6"	21.6 %	75.8 %
18"	20.0 %	77.0 %

Tippings of medium and low pruned bushes are very low in tannin content and in other constituents, and this accounts for the poorness of teas made from the first flush.

In addition, the quality is affected by the number of leaves taken with the shoot, and the inclusion, or otherwise, of *banjhi* and hard leaves and shoots. An estimation of the tannin content of *banjhi* shoots, compared with normal shoots from the same bushes, gave a value of 10 per cent. for the *banjhi* shoots as against 13 per cent. for normal shoots.

The quality of the leaf drops off rapidly as we get further away from the bud. The first leaf is of better quality than the second, and this latter of much better quality than the third, and so on. The stalk, particularly below the second leaf, is of very poor quality. Thus, the inclusion of the third leaf, with its quota of stalk, lowers the average quality of the shoot to a very marked degree.

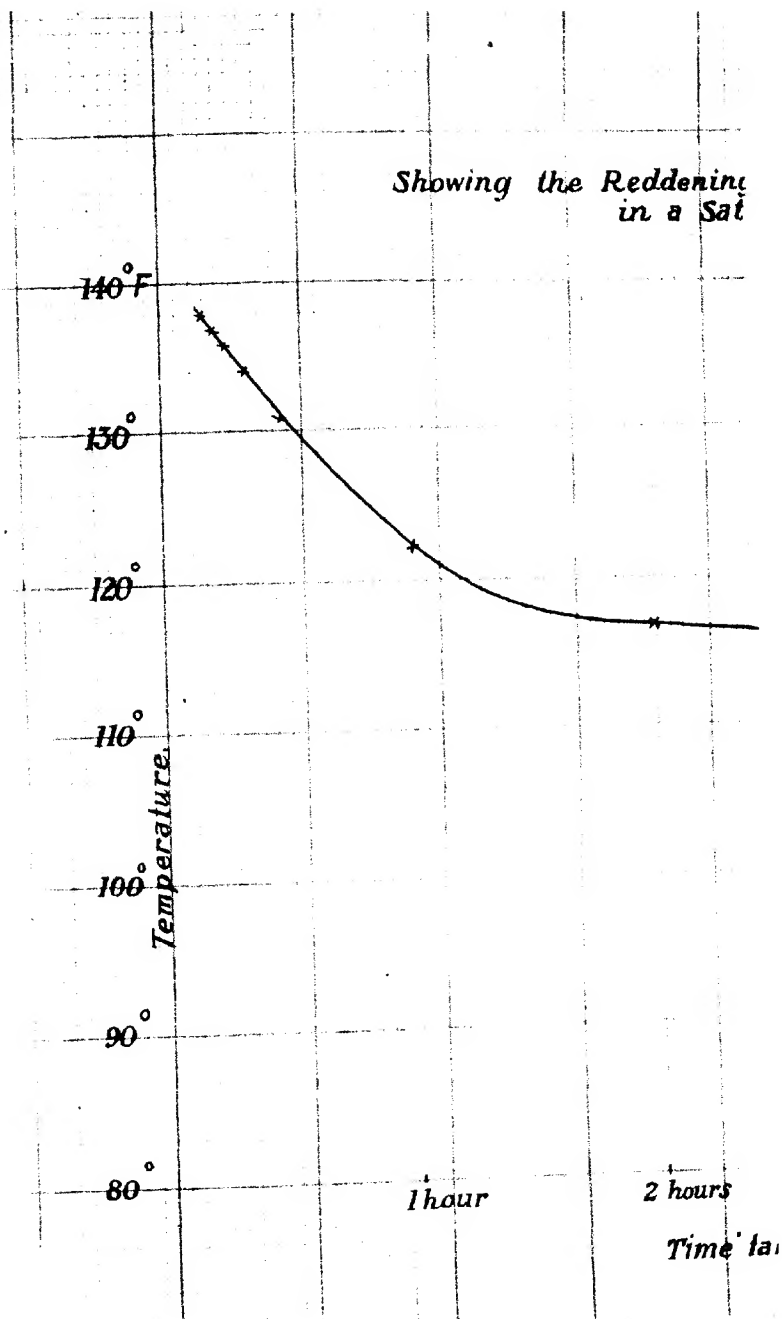
The following table gives the moisture and tannin in the various parts of the shoot.

	Tannin %	Moisture %
Bud	27.94	76.6
First leaf	27.94	78.6
Second leaf	21.34	78.6
Third leaf	17.84	76.9
Fourth leaf	14.50	74.8
Upper stalk	11.70	86.9
Lower stalk (2nd to 4th leaf) ...	6.43	84.6

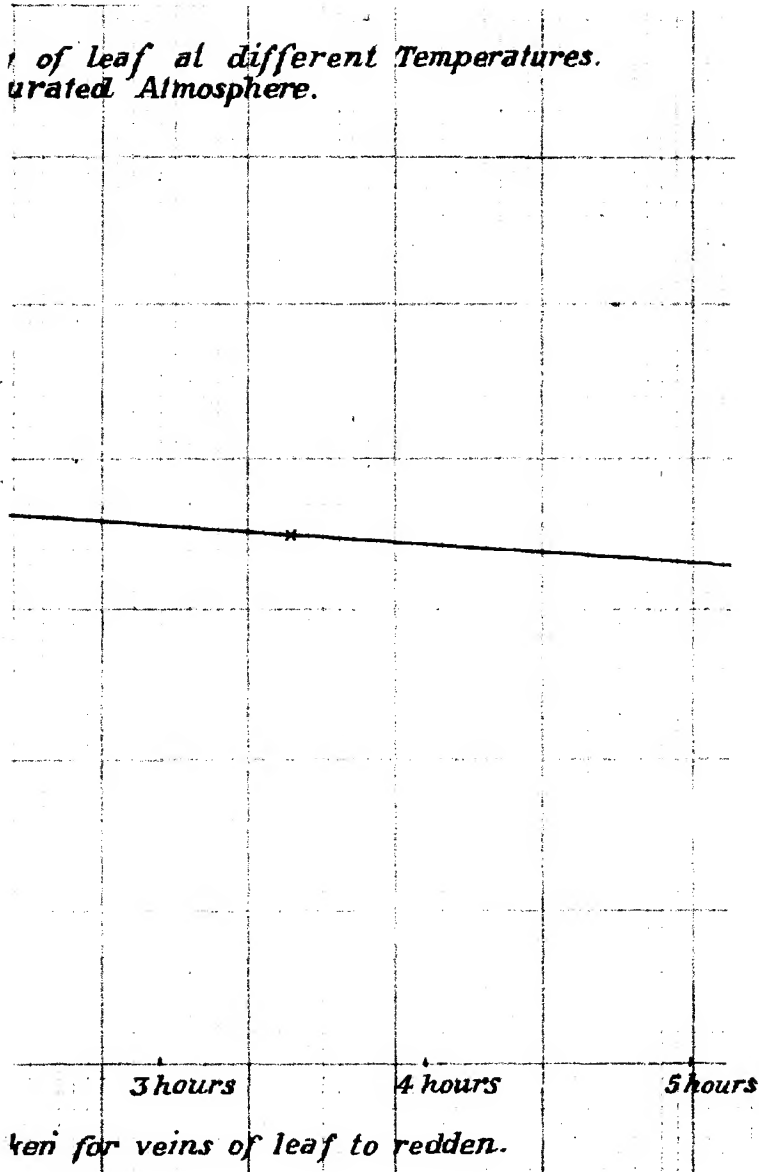
In general one can say that fine and close plucking above a long growth of old wood, produces teas giving the thickest and most pungent liquors.

Stalky teas may result however from too close plucking, particularly towards the middle and end of the season when the new wood has had time to harden. It is therefore generally advisable, if stalk is to be avoided, to leave a leaf for one round of plucking, about the end of June. During the early part of the season, there is little chance of stalk even from "janum" plucking, since the new wood has had no time to harden up.

*Showing the Reddening
in a Sat*



*of leaf at different Temperatures.
urated Atmosphere.*



Whenever growth is accelerated, by favourable weather conditions, increased manuring, or by any of the factors before mentioned, it is advisable to distribute this additional energy among a large number of shoots rather than to confine it to a few. Thus if tea has been well manured and is in a healthy condition, more twigs may be left as growing points for the following season's shoots, than would be the case on weakly tea bearing many thin and 'banjhi' twigs.

If a branch bears three or four stout twigs it is a safe plan to leave all to bear new wood, rather than to cut out one or two with the object of confining growth to the one or two left in. This does not of course mean that weakly and 'banjhi' twigs should not be removed.

Under these conditions of lighter pruning, there is little risk of loss in quality through manuring or other conditions tending to force growth.

TREATMENT OF LEAF FROM BUSH TO WITHERING SHED.

It is safe to say that the sooner plucked leaf is spread out in the withering sheds, the better. Unfortunately it often happens that a considerable time elapses before leaf can be brought to the factory from the garden, during which time the leaf is lying packed closely in plucking baskets. Apart from mechanical crushing, serious injury may occur to the leaf on account of heating and consequent reddening, which takes place not as a result of the sun's heat, but owing to the action of a ferment on the leaf producing heat which, when the leaf is closely packed, cannot escape.

When tea leaf is heated it turns red after a certain time depending on the temperature. This reddening is connected with chemical changes that take place in the leaf during withering.

Leaf was placed in a saturated atmosphere and submitted to various temperatures and examined for the first sign of redness from time to time. The table below, and the curve opposite,

show the effect of temperature on the time required for reddening :—

Temperature (in degrees F).	Time required for reddening (in minutes).
138	... 10
137	... 11
136	... 15
134	... 19
131	... 31
122	... 61
117	... 120 (2 hours).
115	... 210 (3½ hours).

Leaf in the middle of a plucking basket has been known to heat to a temperature of 140°F. Under these conditions it would take less than ten minutes to redden. The table above indicates that differences of 4-5°F at about 120°F may make all the difference between taking good or red leaf into the factory, and indicates very clearly the necessity for careful attention being paid to the temperature of leaf in the plucking baskets.

The leaf is often kept cool to some extent by leaving a hole down the centre of the basket-full, the leaf being heaped round the sides of the basket.

Apart from this, it is important that the leaf should be weighed in quickly, there being three or four weighings-in during the day, instead of the usual one in the morning and one in the evening. This entails a good deal of extra trouble, but the resultant improvement in quality will be well worth while.

Where the motor lorry or trolley is employed for long distance carting of leaf, the latter should be spread about six inches to nine inches deep on tiers of trays, these being about 18 inches apart. This allows free passage of air between the layers of leaf and prevents heating.

Leaf which comes from the basket red, should be manufactured at once, separately from the remainder, since it is already fully withered from a chemical point of view though physically

under-withered. This question of chemical wither, as opposed to physical wither, is dealt with in the succeeding paragraph.

WITHERING.

When a shoot is plucked and allowed to remain in a normal atmosphere, it gradually loses moisture from its cells, and takes on a flabby appearance and texture, whereby it is fitted for the rolling process after having lost about 10 per cent. of its moisture.

Chemical and Physical
wither.

If carried to excess this drying results in dried, blackened shoots and the edges of the leaves shrivel and turn brown.

The loss of moisture from the tea shoot constitutes the "physical" wither.

In addition, a change takes place in the constituent substances of the leaf, whereby the bitter tannin complex previously mentioned breaks down to give astringent tannin. The change commences only when the vitality of the leaf cells has been reduced to a certain point. Such reduction in vitality is ordinarily, though by no means always, occasioned by loss of moisture (that is, the physical wither), the reason being that it is convenient to run the two processes side by side in practice. Thus when the physical wither has reached a certain stage, the chemical wither commences. Under conditions such as heat of application of chemicals which break down the cell walls, the chemical wither may start without any loss of moisture from the leaf. The reddening of the leaf referred to above is an instance of the effect of heat, and here, of course, the chemical wither has gone too far. A good indication that this part of the withering process is complete is the slight reddening of the veins and mid-rib of the leaf. A more definite and by no means impractical method of determining the state of the chemical wither is to take a definite number of shoots, say 15, and boil them in a small covered saucepan for half an hour with a definite quantity of water (half a pint is a convenient quantity).

The liquor is then poured off into a taster's cup. If this is done on leaf in various stages right through the wither, it will be noticed that whereas fresh leaf gives a greenish liquor, after a certain time of withering, the liquors obtained take on a golden red colour which increases as the withering proceeds. A good wither gives a rich and bright golden red liquor. If the wither proceeds too far, the liquors become dull and brownish.

On a good withering day in the rains it so happens that, after about 18 hours from plucking, the chemical wither is completed about the same time as the physical wither. From our observations, the first ten hours or so are occupied with the physical wither alone. At the end of this time, when, by loss of moisture, the leaf cells have lost vitality to a certain degree, the chemical change commences, slowly at first, but more rapidly later on, since the vitality of the cells continues to drop as the physical wither proceeds still further.

On a very dry day, the physical wither proceeds rapidly, and after a very few hours the vitality of the cells is reduced sufficiently for the chemical change to start. The speed of the chemical change depends on the temperature, so that on a cool day this change proceeds less rapidly than on a hot day. Humidity affects the chemical change little, or not at all, while it has a great influence on the rate of the physical wither. Thus, on a very dry day, though the physical wither is completed in a few hours, the chemical change will still require as much time as on a humid or normal day of the same degree of temperature.

Unfortunately, if the leaf on a dry day were left for the chemical wither to go to completion, the leaf would be crisp and dry owing to the rapid loss of moisture. Thus it usually happens that under dry conditions the leaf has to be collected and rolled before the chemical wither is complete. A remedy for this is to spread the leaf thicker on dry days, so as to slow up the physical wither. In some cases even, spraying the leaf and racks with water is resorted to, to slow down the loss of mois-

ture. This should be unnecessary however, if, when the physical wither is almost complete, the leaf is collected into layers, not more than six inches deep and left for two or three hours, for the chemical change to be completed: the leaf spread thickly should be occasionally turned over to prevent uneven drying. Thicker spreading causes heating.

In connection with successful withering on dry days, the use of shutters made of hessian cloth, spread on thin bamboo slats, has proved very useful in some factories. These may be used so as to close in one or more sides of the withering house, resulting in the exclusion of sun and drying breezes, thus slowing up the physical wither.

More common in North-East India are the very humid days, when so laden is the atmosphere with moisture that its drying capacity is small, and leaf left for 18 hours scarcely loses its original turgidity. Under these conditions the cells continue to retain their vitality and no chemical wither can commence. Thus, the leaf must be rolled when neither physically nor chemically withered, otherwise further keeping in the withering house means a large accumulation of leaf to be manufactured, and the risk of the production of sourness. The only method of overcoming this difficulty is so to arrange things that the leaf is subjected to air of a lower degree of humidity, relative or absolute. This is usually done by passing warm air from the factory over the leaf which is spread on racks in lofts situated above the factory. The drying capacity, as measured by the relative humidity of air, is increased by raising the temperature. Thus air passing through outside withering houses may be at or near saturation point and incapable of taking moisture from the leaf. When this air has been heated in the factory it becomes capable of absorbing more moisture. This air is usually led into a large chamber above the drying room, in which it is bulked and then drawn or forced by fans over the racks of leaf. The total distance over which the air should be drawn depends on the state of saturation of the entering air and its speed of flow. As the air passes over the leaf

it picks up moisture and gradually becomes saturated; in which condition it is of no further use as a drying agent. The use of the wet and dry bulb thermometers will indicate the state of saturation, the readings of both bulbs, being the same, indicating full saturation.

In Ceylon it is found that if the length of the withering loft is 100 feet and the air at 85°F takes two minutes to pass through, starting with a relative humidity of 70, a good wither is obtained in about 24 hours. A good wither in Ceylon however would be considered an over-wither in North-East India. Here, a good wither is obtained when 100 lbs. of leaf has dried to 70-75 lbs., whereas in Ceylon 100 lbs. of leaf would weigh not more than 55 to 60 lbs.

In Ceylon the air temperature in the lofts is seldom above 85° at the inlet, whereas in North-East India, where lofts are used, temperatures as high as 100°F are the rule.

It is certain that by use of too great a temperature, i.e., above 100-110°F, in withering, definite loss in flavour results.

One of the most important considerations in connection with withering is the spreading of the
 Spreading of leaf. leaf. An even spread of 1 lb. leaf per square yard of rack allows of a reasonably thin spreading of the leaf and results in an even wither.

If possible an even thinner spread of leaf should be made, but that cited above is the thickest that should be allowed.

On this basis, a fairly good estimate of the amount of space required for withering can be obtained. It is found that on an average big day in the rush season, $\frac{3}{4}$ per cent of the total crop is manufactured. This, for a garden whose annual outturn is 10,000 maunds of tea, is 75 mds. of tea or about 300 mds. of green leaf. At the rate of 1 lb. to 9 sq. ft., 2,16,000 sq. ft. of withering space is required to cope with this quantity of leaf. If less space than this is available on a garden making the above-mentioned crop, underwithering during the height of the season is a certainty.

The question as to whether hessian cloth is superior to wire mesh in withering houses, has usually been decided by planters in favour of the former, and certainly a better wither is obtained on hessian cloth than on the wire netting of the size of mesh one usually sees, since on hessian "chungs" there is less chance of the buds and small leaves drying up and blackening. There is however, more chance of souring with hessian cloth, since it forms a better harbourage for harmful bacteria unless carefully watched, and replaced when rotten. Wire netting of a small mesh gives a very good wither and does not allow the small shoots to hang through and blacken.

A most important point in connection with the prevention of souring bacteria and ferments is the careful removal of all stale leaf before spreading a fresh day's consignment.

It would be found of very great assistance in getting evenly withered leaf to make a regular routine of having hard and banjhi leaf picked out by boys after the leaf has been spread. Uneven leaf, containing much banjhi and hard leaf, is impossible to wither evenly, and since an uneven wither results in uneven rolling and fermentation and the consequent production of uneven greenish infusions, it is of primary importance to see that as good leaf as possible comes into the factory.

The temperature in corrugated-iron roofed withering houses varies considerably and often results in uneven withering. While the lower storeys are comparatively cool and constant in temperature, the upper storeys, close under the roof, often reach temperatures of well above 100°F during the day time.

Temperatures of over 120°F have been obtained immediately under the iron roof, and 110°F is a not unusual temperature just above the surface of the leaf in the top racks.

The effect of the heat on a dry day is to wither the leaf physically in a very short time, so that it may become much physically overwithered. On a wet day, though the physical

wither would not proceed at such a speed, the effect of the heat is to cause reddening of the leaf, and a condition similar to that obtained in baskets of overheated leaf results. Leaf on the upper storeys should be carefully watched on hot days and removed when ready, since the time required to produce the wither will be very much shorter than for the remainder of the leaf. Such conditions as those above mentioned do not arise so readily in thatched roof withering houses, which for this reason are superior to the "tin roof" type.

The lower racks should be completely filled up with leaf before using the top racks, so that the latter are only used when absolutely necessary.

There is often considerable difference in the rate of withering of morning and evening leaf. Twelve o'clock leaf spread during the early afternoon has a few hours of dry and warm weather and dries off more quickly at first than evening leaf spread at about 6 o'clock. Thus, that stage of physical wither, when the chemical wither commences, is reached in a shorter time with 12 o'clock leaf than with evening leaf. If the same period of withering is given for both, the morning leaf gets usually the fuller chemical wither, and this probably explains why better teas are often made from morning leaf.

Other points, such as the fencing in of the houses, careful inspection of, and prompt attention to, damage to the racks, good lighting for night work, and in fact everything which assists in maintaining cleanliness and efficiency, helps enormously in the production of good, evenly withered leaf, without which it is impossible to produce the best tea.

ROLLING AND SIFTING.

The effect of rolling is to bruise and twist the leaves so that, the juices being exposed to the action of air and mixed up with the fermenting organisms, the process of fermentation, including oxidation, can go on. Thus fermentation may be said to start the moment the leaf is bruised.

From the few experiments carried out on the speed of rolling, it appears that, so long as the number of revolutions is about the same in each

Speed of rolling. . . case, speed of rolling has little or no effect on the tea produced. If slow rolling is carried out, the time of rolling should be more than proportionately longer than if fast rolling is done. The reason of course is that in fast rolling there is more shearing strain on the leaf, and consequently more efficient bruising of the leaf. When the rolling is slow, extra time must be allowed, to compensate for the lower efficiency of the roll.

To experiment on the question of fast and slow rolling is difficult because in practically every factory all the rollers revolve at the same rate. In one factory where rollers were fitted with different pulleys, one roller made 55 and another 65 revolutions per minute. Leaf was rolled for 60 minutes in the faster one and 71 minutes in the slower one, thus ensuring that the leaf in both cases was submitted to the same number of revolutions, *viz.*, about 3,900. There was practically no difference in cup between the two samples.

In another case, two rollers, one making 58 and the other making 78 revolutions, were employed, and the rolling was carried out for the same time in each case. Lasting as it did for one hour, the slowly rolled leaf received 1,200 less revolutions than the fast rolled. The fast rolling gave 20 per cent. B. O. P. and ten per cent. O. P. whereas the slow rolling gave 10 per cent. B. O. P. and 20 per cent. O. P., but much more tip than the fast rolling. Apart from this the liquors from the fast rolled teas were better than those of the slow rolled.

So far as hard and light rollings are concerned, repeated experiments have shown that hard rolling gives stronger teas but more stalk than light rolling.

The rolling system in a factory is generally controlled by the number of rollers. It may be said that with a system consisting of two half-hour rolls and a final short one before firing, one big roller will cope with just over 1,000 maunds of plicca tea in

a season, or four rollers can manage about 5,000. maunds. This figure only constitutes a very general guide and will not do for a district where the season is a short one and the crop crowded into four or five months. In estimating the machinery required for a factory, the average heavy day should be considered and sufficient machinery put down to cope with such a day.

A system of rolling suggested as being generally suitable runs on the following lines :—

Ten—Thirty minutes, light pressure

Forty-five minutes heavy pressure with about ten minutes on five minutes off or seven minutes on three minutes off

Ten minutes final rolling after fermentation (for appearance alone).

This system which includes *kutchu* sorting between the first and second roll is calculated to give tip. Many gardens roll hard the whole time and make broken teas which sell for their liquors. It is not suggested that these gardens should alter their rolling process since the teas produced meet a definite demand and fit in with the blending scheme at Home. But if at any time "tip" is needed, a light first roll will help to ensure that any tip present shall be visible. The final roll of ten minutes after fermentation is given for its physical effect only and in many cases no improvement has been recorded from the inclusion of this roll. The matter is one for experiment on individual gardens.

It is of interest here to note the difference in the percentage of fine mal made by coarse and fine plucking. When two leaves and bud are plucked, the percentage of fine mal made under the conditions of rolling above mentioned, and using No. 4 mesh in the first sorting and No. 5 or 6 mesh in the second, is roughly 30 per cent. of the total roll. If three leaves and bud are plucked, the same conditions give only about 17 per cent. of fine mal. Frequent sifting and ball-breaking is desirable since more fine mal is extracted, and therefore protected

from further rolling, which it not only does not require, but which definitely harms it by blackening the tip.

Hard rolling exposes red stalk and fibre but gives good liquor. Light rolling gives a better appearance but poorer liquors if the rolling is continued only for the same time as with the heavier pressure. The appearance of red stalk is also influenced by the wither, and the fuller the physical wither the less likelihood there is of red stalk being exposed by harder rolling.

The speed of the roller is a factor worthy of attention. Early in the season, with only part of machinery in use, the tables often revolve at speeds in the neighbourhood of 80 revolutions per minute.

In Ceylon rollers revolve about 45 times a minute but the rolling period may be as long as three hours. Ceylon teas have both appearance and liquors. If this method of rolling were to be adopted in North-east India many more rollers would be needed.

For the same pulley speed, a double acting roller does more efficient rolling than a single acting roller, the actual shearing stress on the leaf being twice as much in the former than in the latter type. This is a point to be borne in mind when adjusting roller speeds. The double acting roller thus has the same effect as faster rolling, compared to a single roller, and tends to produce more stalk.

The temperature of the rolling room is of importance and influences the temperature of the leaf in the roller. The heat mechanically generated in the roller is very small and most of the rise in temperature here is due to the heat of fermentation. During the first roll the heat developed is small, partly on account of the lightness of the pressure and partly because the fermentation has not well started. The heat developed in the second roll is greater, but is lessened by alternately raising and lowering the pressure cap. In a cool factory, after 15 minutes' hard rolling in the second roll, a rise of only 3°F was observed. In hot

factories, however, temperatures as high as 105°F have been recorded during the second roll. The temperature of the rolling room should be kept the same as the fermenting room and 82°F is suggested as a practical possibility for plain-situated gardens.

The practice of making the rolling and fermenting room all one is good in that it ensures a cool rolling room, although it is harder to control temperatures in a large space than in a small one. For this reason such an arrangement may not be ideal from the point of view of the fermenting room.

In some factories, air is blown into the roller for cooling purposes. It is preferable to reduce the temperature by other means, for this practice causes a certain amount of drying and oxidation of the leaf with the production of poor colours.

For cleaning down rollers after a day's work clean water delivered through a hose under a good pressure is usually sufficient. A thorough weekly cleaning with a steam jet has been found very satisfactory in many factories and destroys any bad odours which may arise through old leaf collecting in crevices. As an emergency measure, where a steam jet is unobtainable and water alone does not remove unpleasant odours, a weak permanganate solution may be used. This does not affect the metal or wood parts. Permanganate should be carefully removed with clean water afterwards. Under no circumstances should soda, lime, or any alkaline washes be used, on account of their effect on the colour of the leaf.

A few remarks on the capacity of rollers may be of interest. In Upper Assam the open top box roller is much in favour for the first roll. The capacity of this machine is about six maunds of withered leaf, but in some cases the capacity is increased by addition of wooden extensions to the top.

The "Rapid" machine takes four maunds of leaf and is capable of dealing with 700 maunds of tea in the course of the season.

The "Metallic" takes six maunds of leaf and is capable of 1,000 maunds of tea in the season. Thus for a garden making 10,000 maunds of tea, ten rollers of the "Metallic" type are necessary.

To sum up our remarks on rolling, it seems evident that the best results are obtained by rolling to the greatest possible capacity of the factory with frequent separation of fine mal. If the capacity of the factory is small, then fast rolling for a short period gives the best results, but the ideal would be a slow (55 r. p. m.), and hard roll, carried on as long as possible, even so far as to occupy the whole time of fermentation, the coarse leaf then going straight from the ball breaker to the drying machine. Of course, in such an ideal case as this, the coolness and humidity of the fermenting room would be a matter of very great importance.

The flat type of *kutch*a sifter is preferable to the rotary type, which is apt to get clogged with leaf at the corners where the battens are nailed to the mesh. This leaf becomes over-fermented unless it is removed. The difficulty can be overcome however by having easily removable sides to the rotary type of sorter, which latter is considered by some to be more efficient than the flat type.

Unless the balls are all broken in the *kutch*a sorter or ball breaker the fermentation will be uneven, with resulting unevenness in the infusion.

Two meshes are sometimes used in the *kutch*a sorter, the first two-thirds being of No. 4 mesh and the last third of No. 5 or 6 mesh. This arrangement is said to give a more even mixture of fine leaf than that given by a sorter containing the same mesh throughout.

FERMENTATION.

As soon as the leaf is bruised and broken in the rollers the fermentation process commences. The contents of the leaf cells are exposed to the action of the air and to fermenting organisms, whereby a reddish-brown colour and, at the same time, to a greater or less degree, an aroma is developed.

The red colour is due to the action of air on the pungent tannin, in the presence of enzymes.

Chemistry.

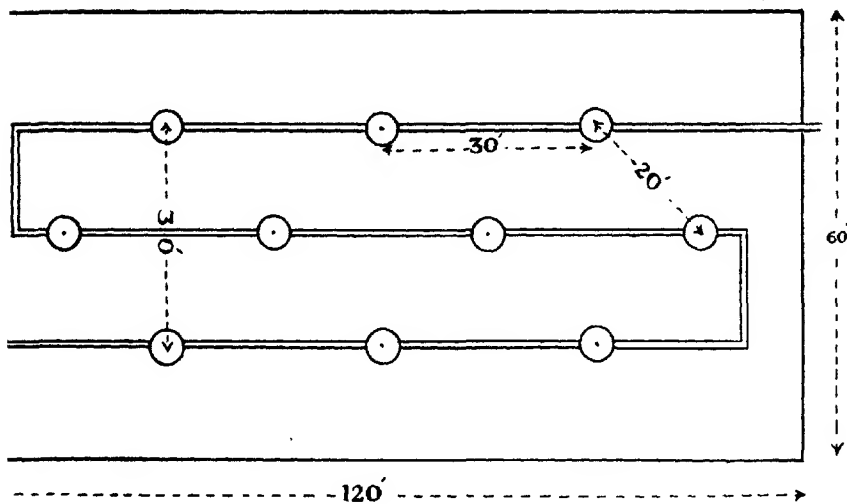
These latter are complex bodies which have the effect of increasing considerably the speed of a chemical change which, in their absence, would proceed very slowly. Thus the reddening only takes place in the leaf when, by mechanical damage, such as rolling or heating; or by chemical damage, as for example the application of chloroform vapour, the cell walls are broken down so as to allow the enzyme and the tannin to come into contact with air. The chemical change is a complicated one and many substances varying in colour from golden red to purplish brown are formed. In a very humid atmosphere the formation of the reddish substances is encouraged, but if, as happens often, the atmosphere is not sufficiently moist, dark brown substances result. These latter are grouped under the name "tannin brown" while the reddish ones are called "tannin red." In obtaining good colours both for liquors and infused leaf, our object is to eliminate mainly the tannin brown, and to encourage in its place, a certain proportion of tannin red. If too much tannin red and tannin brown are formed, there is consequent loss of astringent tannin, and although coloury liquors result, they are flat, lacking in briskness and pungency.

If, on account of too thick spreading of the rolled leaf, or of inefficient ballbreaking, the leaf ferments unevenly, the result is an uneven infusion containing greenish pieces of leaf.

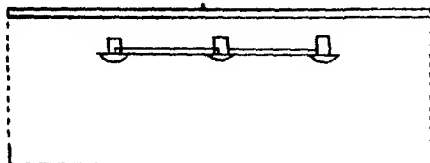
It will be seen from the above remarks on the chemical changes that, to obtain the best result from fermentation, certain conditions must be fulfilled. The most important point is the humidity, which should be as near 95 per cent. as possible.

Arrangement of Humidifiers in Fermenting Room.

Plan



End Elevation



Side Elevation

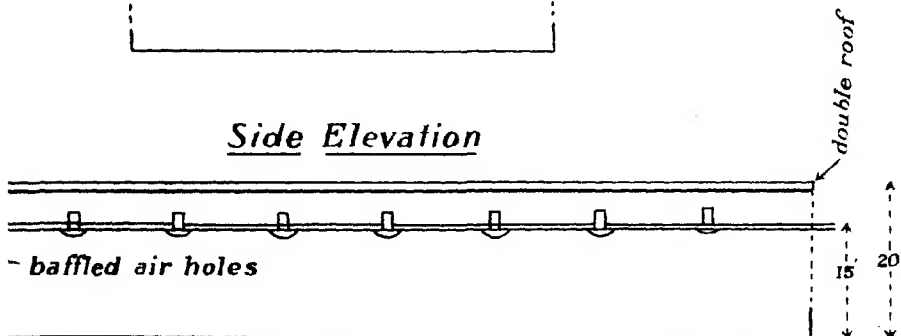


FIG. 1

The humidity can only be maintained at 95 per cent. throughout the season by the use of humidifiers. These are devices for charging the air in the room with moisture, in the form of a fine "atomised" spray, or rather vapour. Two types have been seen working efficiently in tea house fermenting rooms. One is known as the "Vortex" Humidifier (Messrs. Mather and Platt, Ltd). The system requires a 100 lbs. pressure of water through a pipe about 15 feet from the floor of the fermenting room passing along both sides and down the middle of the room with the humidifiers attached as in Fig. I.

The humidifier consists essentially of a nozzle through which the water is forced in a fine cloud of spray which impinges on an inverted metal cone. This forces the spray out over a wide area. There is in addition a filter for cleaning the water before it is sprayed, thus preventing the nozzle from being stopped up. The filter is automatically cleaned when the humidifier is shut down. To obtain the best results the humidifier should be not less than 15 feet from the ground. This would in many cases necessitate reconstruction of the fermenting room, since many rooms are low built. One humidifier, at a height of not less than 15 feet from the ground, covers, at its best efficiency, an area of 400 sq. ft.

Another type of humidifier of simple and inexpensive design is known as the "Acrozon" humidifier (Fig. III).

Here an air pressure of about 60 lbs. is required but no water pressure. The water drips through a nozzle and at an angle to this the air is blown from a fine nozzle and, impinging on the water drops, scatters them as a fine spray. This humidifier is at present working very efficiently in tea fermenting rooms. The Sullivan's air compressor, giving a pressure of 60 lbs. per sq. inch, is a convenient type to use for obtaining the requisite air pressure.

A fairly efficient home-made humidifier can be constructed from the lance and nozzle of a "Four Oaks" sprayer as used

for spraying tea. Fig. IV illustrates the construction of this type of humidifier.

A pressure of 100 lbs. per sq. inch of water is required. The lance and nozzle are enclosed in a cylinder of metal about 18 inches long and ten inches diameter, fitted with an inverted cone for spreading the spray, and a cone trap for removal of excess water.

A considerable improvement in conditioning the atmosphere of a fermenting room can be made by the use of wet purdahs, but care is required in keeping the latter clean and free from souring organisms, especially if the method of spreading the cloths on the beds of fermenting leaf is employed. Here it is advisable to keep the cloth just clear of the surface of the leaf by laying it on bamboo laths resting on wood blocks slightly thicker than the spread of the leaf.

Apart from the humidity of the air, other considerations such as temperature and air flow are of importance. As the temperature rises it is more difficult to maintain a high degree of humidity, and in addition, the chemical changes in fermentation, causing the reddening of the leaf, proceed at a greater rate. Thus a shorter time of fermentation is required at higher temperatures than would be the case under cooler conditions. A practical maximum room temperature for average gardens in the plains is 82°F during the monsoon weather. This should not be exceeded but lower temperatures are desirable when it is possible to obtain them.

The presence of draughts of air from outside the fermenting room has a seriously harmful effect on fermentation. This air is nearly always drier than the normal fermenting room atmosphere and is often warmer. The result is invariably poor colours and in many cases flat liquors. Of course, there should be a slow and steady change of air in the room, otherwise staleness and bad odours arise, but anything approaching a breeze is most undesirable. Walls with well baffled air holes above

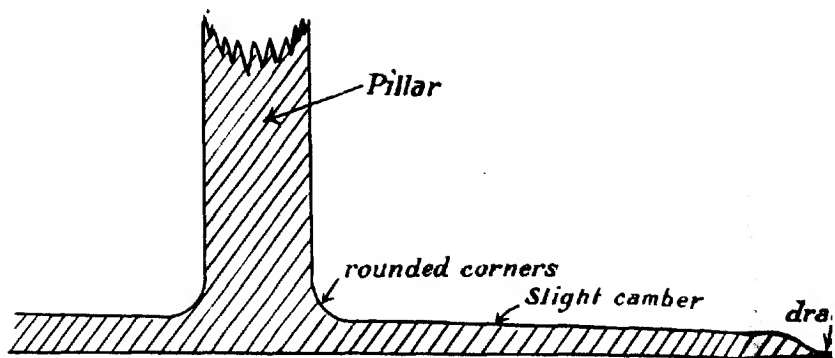


Fig II. Bed of Fermenting Floor.

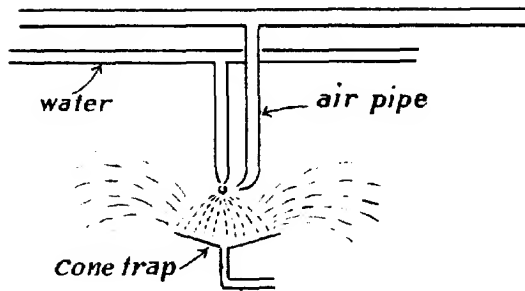


Fig III.
"Aerozon" Principle
Humidifier

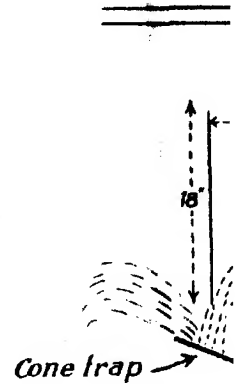


Fig IV Sprayer
Humidifier

about four feet from the ground, and provided outside with adjustable bamboo blinds, ensure a steady air flow and obviate draughts.

A point requiring much attention is the construction of the fermenting room itself with special reference to the floor. The room should

Construction of room.

be not less than about 16 feet high, but if too high there is greater difficulty in keeping the air saturated. The best position for a fermenting room is to build it into a withering house. This ensures that the sides of the room and the roof are protected from the sun, and rooms built in this way are generally much cooler than the rooms built separate from the withering house. In the latter case there should always be a double roof, otherwise it will be found impossible to maintain coolness.

The shape of room which allows humidifiers to be worked efficiently is a rectangular room about twice as long as it is broad. The diagram illustrates how the humidifiers are placed in a room of the abovementioned proportions. The room should be constructed so that there is sufficient light to allow a proper supervision, although direct sunlight or direct reflection from the sky should be avoided.

With regard to the material used for the fermenting floor, opinions generally favour cement in preference to glass although the majority of experiments have shown no actual difference as far as the teas produced are concerned. Cracks and crevices on the beds are to be avoided since they are difficult to clean, and harbour sour leaf and juice and harmful bacteria.

For the same reason there should be as few pillars as possible in the room and the corners formed at the junction of the pillar and floor should be rounded off to facilitate cleaning. In a similar manner, the edges at the roof of the four walls can be rounded off. The beds should have a slight chamber to allow any excess water, or water used for swilling the floors, to run off readily. A cross section of a bed is shown in the accompanying diagram.

When a new floor is laid down, or a piece of floor repaired with fresh cement, poor colours and flat
 Cleaning and treatment of floors. liquors are often obtained owing to the action of the lime in the cement on the tea juices, in particular on the tannin. This surface coating of lime may be removed by swilling the floor down with the juice from a roll of "kutchu" leaf, whereby the lime is dissolved out from the surface layer of cement. After leaving the juice in contact with the floor for about four hours it should be swilled off with clean water. This procedure should be repeated three or four times to obtain the best results.

Ordinarily a floor should be cleaned by swilling down with water only, after each day's manufacture. Scrubbing may expose a fresh surface of lime and in addition appears to remove certain organisms favourable to fermentation. If, however, a sour smell or bad odour is noticeable the floor should be sluiced with permanganate (of ordinary Condy's fluid strength) and then washed thoroughly with cold water. It will usually be found that bad smells arise, not from the beds themselves, but from cracks and crevices, or from the vicinity of the trolley line if such is used for transporting leaf to and from the fermenting room. On no account should alkaline washes such as lime wash or soda wash be used for swilling down floors since these have a harmful effect on the tea.

The use of iron shovels in contact with the rolled leaf is to be deprecated, owing to the action of the tannin in the juices with iron. This action has been referred to earlier on, and though little actual harm would result in this instance, it is one of the small points in manufacture which may make the difference between good and mediocre teas.

During fermentation pungent tannin is being changed to tannin red and tannin brown, producing
 Spreading and time of fermentation. colour and strength, and thus pungency and briskness are gradually lost, and give place in extreme cases to flatness. It is our object to pre-

serve as much briskness and pungency as possible and at the same time to obtain as strong and coloury a tea as possible. By thickening the spread of leaf, this may be to some extent achieved, but there is then a risk of reducing the air supply to such an extent that the fermentation almost ceases and the leaf remains green. This occurs especially if the spread is above about 5 inches. Apart from this, where the fermentation does go on, the heat formed is confined to a limited space and the resultant rise in temperature causes the fermentation to proceed so rapidly that it gets out of hand and much briskness and pungency is lost.

The best way of meeting the difficulty is to spread the leaf about two inches to three inches deep in a very moist atmosphere, and it may be necessary to restrict the air supply somewhat by the use of wet cloths spread over the leaf, as described above, though a fairly plentiful supply of moist air is desirable. When cool temperatures are the rule, as during the end part of the season, the time of fermentation may be lengthened or the spreading made thinner. The actual time required for fermentation depends on many factors but should be as short as possible in order to obtain the maximum briskness and pungency together with the necessary colour.

If strength and colour are desired and briskness and pungency are not so much in demand, the fermentation will have to be lengthened. The following experiment illustrates the point. Leaf was fermented in three batches, one for three hours, another for three and-a-half hours, and a third for four hours. The first mentioned tea was brisk and weak and was valued at 16 annas.

The $3\frac{1}{2}$ hours fermentation resulted in a less brisk, but rather stronger tea, which with no stand-out characteristic was valued at 14 annas. The third tea fermented for four hours, although somewhat lacking in briskness, was very strong and obtained $16\frac{1}{2}$ annas.

From another experiment on time and spread of fermentation the following types of fermentation gave identical liquors—

2½ inches spread with 3½ hours fermentation					
3½	“	“	“	4½	“
3	“	“	“	6	“

The temperature of the leaf is generally somewhat higher than that of the air above, owing to the heat developed during the chemical changes. In order to obtain the maximum control over fermentation the temperature should be as near to that of the air as possible, *i.e.*, about 82°F. A practical maximum temperature for the leaf is 86°F, which should not be exceeded if the best results are desired. Actually the temperature rises during the first 2½—3 hours and then remains steady for 2½ hours, after which it drops.

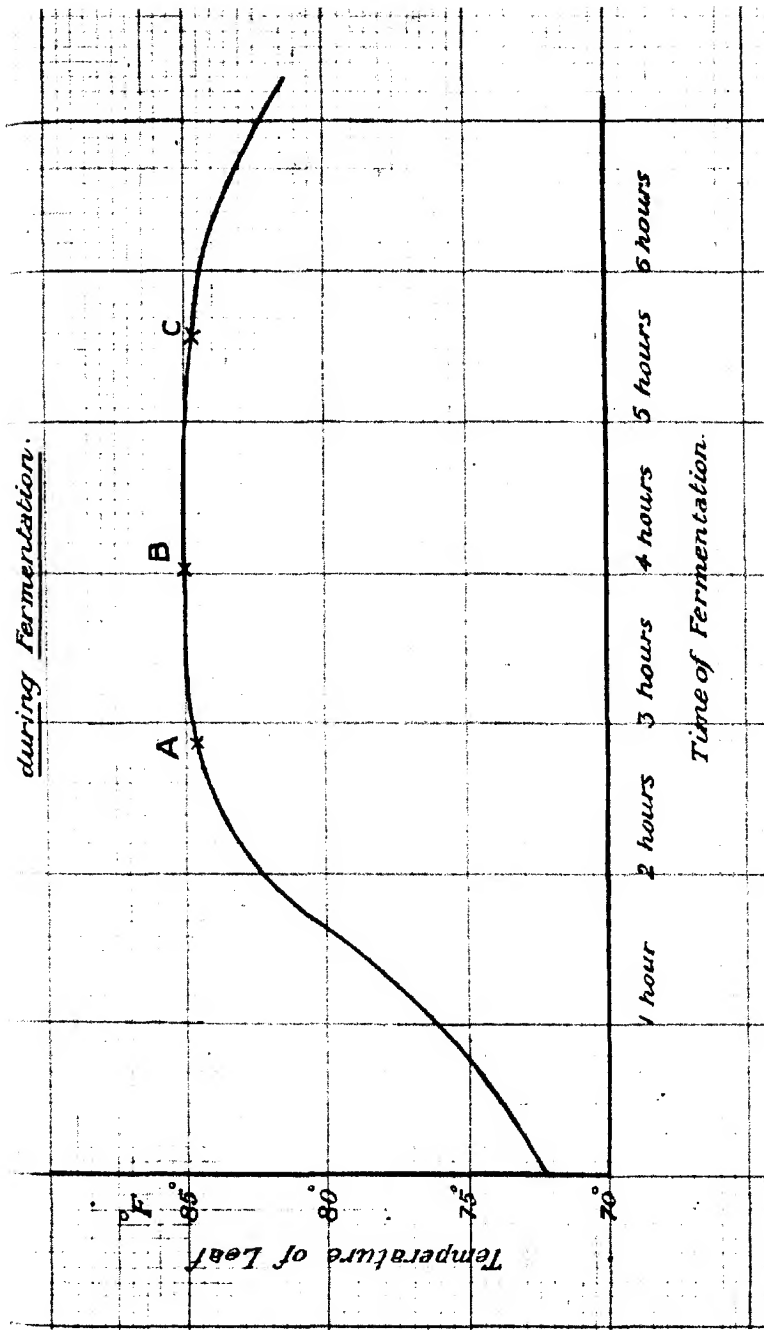
Under normal plains conditions, when the temperature reaches the maximum at A (in the diagram shown opposite), an aroma known sometimes as the “first nose” develops, and this is usually the best time to remove the leaf, to obtain a brisk and pungent tea.

The “second nose” develops after another hour (at the point B on the curve) and the tea made after leaving the leaf this extra hour is stronger but less brisk. If left for another 1½ hours, a third nose develops (at C), but by now the tea, though strong and coloury, is usually entirely lacking in briskness and pungency and is flat. This indicates that the fermentation has proceeded to a too advanced stage, and after this, the temperature begins to fall off.

To summarise these remarks on fermentation, the best conditions in general are—

- (a) A cool saturated atmosphere.
- (b) A thin spread.
- (c) A fairly short fermentation.
- (d) A fairly plentiful supply of moist air.

Bad colours are sometimes improved by adding aerated water during the rolling, the production of bright red colours



being assisted by the presence of acid in the form of carbonic acid. No harmful effects are possible since the acid is driven off during firing.

Good even colours have been obtained by turning the leaf on the fermenting floor once every hour. The production of poor colours in the first few gunnies of the day's manufacture is due to the fact that these are often made from physically over-withered leaf. Here the use of aerated water in the rollers might be of assistance.

During the morning when the atmosphere is naturally more humid the best colours are obtained, but during the afternoon the atmosphere is drier, and unless care is taken to humidify the fermenting room artificially, poor colours may result.

Apart from the fermentation conditions, colours are influenced by the wither. A wither on the light side tends to the production of bright colours, while the reverse is the case with an over-wither.

A chemically well withered leaf requires shorter fermentation than leaf chemically underwithered.

Dull green infused leaf is an indication of a chemical underwither coupled with an overwither physically. The latter usually results in the leaf being too dry in the fermenting room. If, however, the physical wither is correct, or on the light side, the leaf is much moister in the fermenting room, and under these conditions, a chemical underwither gives bright green infused leaf.

A dry fermenting room results in dull colours.

FIRING.

The main object of firing is to stop the fermentation process at a desired stage, by destroying the fermenting organisms and enzymes and by the removal of moisture. In addition it is certain that some of the substances present in the leaf are changed by the heat and give the "malty" taste and smell peculiar to fired tea. The change is known as caramelisation.

and is similar to the change taking place when sugar is carefully heated in a pan so that it takes on a brownish colour, and has a taste and smell of toffee, or caramel. The substances affected have a "cabbagy" flavour in the fermented or kutchu leaf and lose this undesirable characteristic when fired.

During the process, a certain proportion of valuable constituents of the tea is lost. This is to a certain extent unavoidable, but the loss may be minimised by careful adjustment of temperature and air blast.

The chief loss sustained is of those substances which give rise to flavour and aroma, and are volatile in steam. The higher the firing temperature the greater is the ease with which they evaporate along with the moisture in the drying leaf. It is therefore our object in firing to reduce the temperature to a minimum compatible with efficiency and the production of teas that will keep, so as to reduce loss in flavour to a minimum.

Some idea of the loss of flavour sustained in firing can be obtained by infusing equivalent quantities of leaf before firing and after firing. Of fermented leaf three times the weight used for an ordinary tea infusion is taken. On the surface of the liquor from undried leaf, an oily film, not usually apparent in an infusion of dry tea, is noticed. This film consists of the substances giving aroma and flavour. By taste and smell the extra flavour in the liquor of undried tea is apparent.

In addition to the loss of flavour there is also loss in caffeine, but this also is greatly minimised by low temperature firing.

In drying a body which is saturated with moisture such as a piece of clay, or vegetable pulp, it is necessary to avoid too rapid drying, since if the surface dries quickly a hard outer case is formed and the moisture inside cannot readily escape. In the case of brick-making this would result in bursting of the bricks. In any case

the result is incomplete drying. This may occur in the drying of tea, and in consequence care must be taken to ensure even evaporation of moisture throughout the leaf. This is done by allowing the tea to meet a hot moist atmosphere, initially, so that the fermentation organisms are destroyed, and drying takes place evenly till, when the leaf comes out finally, it is in a stable condition and can be preserved for a long time without serious change taking place among the constituents. If tea has been dried too quickly in a dry atmosphere the inside of the leaf remains moist, and later on, the slow chemical changes taking place are evidenced by falling off in briskness, quality, and general characteristics. The tea may even go mouldy in extreme cases.

Fermentation appears to be stopped at a temperature of 150°F, or considerably lower in a blast of air. Thus it is found that a temperature of 120°F for the air coming out of the dryer is sufficient to ensure that there is no stewing of the leaf in the initial stages of drying.

Leaf enters the first dryer at approximately 66 per cent. moisture and leaves at about 30 per cent. (assuming a "12-anna" fire). Experiments on the rate of loss of moisture in the leaf throughout its passage, have given the "drying curves" shown opposite. Along the vertical line are marked percentages of moisture in the tea, and along the horizontal, the position of the trays in the machine. No. 1 is the top tray and No. 6 the bottom tray. Samples of tea were taken from the trays under different conditions of firing, the moisture determined and plotted so as to give a curve representing the progress of the drying.

The first curve represents a steady drop in moisture throughout the machine, indicating correct firing conditions.

No. 2 curve is obtained from an overloaded machine. There is an insufficient air supply to cope with the quantity of leaf going through, and though the temperature of the incoming air will be normal or

above normal, by the time the air reaches the upper trays, the heat has already been used to dry the leaf lower down. Thus the leaf entering the machine meets air at too low a temperature, and so saturated with moisture that it has little drying capacity. The result is "stewing" or fermentation in the machine. It will be found that increasing the air supply does not always effect an improvement since the leaf may be spread too thickly and the blanket so formed does not allow air to pass through the trays. The remedy here lies in thinner spreading. It is usually the case that overloading is accompanied by high firing temperature, since the leaf must be brought out at about 12 annas dry, and this drying has to be accomplished in the lower half of the machine. By spreading thinner, with a lower temperature and an increased air flow, overloading cannot occur and there is great improvement in the quality of tea made.

In the third case, resulting from too high a temperature at the top of the machine, the air is too dry. "Case hardening" and blistering. This often occurs when the bypass or auxiliary air duct is used. The wet leaf meets hot dry air, and is dried quickly, especially on the outside, and is "case hardened." The moisture enclosed within the leaf, in trying to escape as steam, creates minute blisters on the surface of the tea. The tops of these get rubbed off in sorting, and the result is a grey tea. This blistering must not be confused with blistering due to high firing alone, when the tea is actually burnt.

A more serious consequence of too rapid initial drying, is the deterioration in quality of the teas thus made, on keeping. Some of the chemical reactions of the fermentation process continue to go on inside the leaf owing to the slightly damp conditions. These reactions destroy briskness and produce a flat tea. (In extreme cases the tea turns mouldy).

To obviate "case hardening", the extra air duct or bypass provided should be used with great care. The temperature of firing can also be reduced, but there should be no need to reduce the air blast.

Experiment shows that the best firing temperature for machines such as the Jackson's "Empire" or Davidson's "E. C. P." is not more than 180°F, while very excellent results have been obtained firing at 170°F. This necessitates a full air blast and usually means increasing fan speeds 50 or 100 revs. per minute above the speed indicated by the makers.

The best conditions for first firing are embodied in these four points.

- (1) Low temperature—180°F.
- (2) Full air blast.
- (3) Thin spread of leaf.
- (4) Speed adjusted so that a "12-anna" fire is obtained (probably second fastest speed).

It is important that the tea should come out of the machine at 12 annas. One or two failures in low firing have been traced directly to the neglect of this essential point. Under the conditions set forth above, the temperature of the air at the exit will never be found to be below 115°F, usually round about 120°F.

In all experiments where low firing (180°F) has been compared with high firing (210°-220°F), and where a 12-anna fire has been obtained in both cases, the low fired teas have been valued at not less than ½ anna per pound better than the higher fired teas. Often the difference was considerably more, due to increase in strength, quality, briskness, and tip in the lower fired teas. It was noticed that at 220°F a considerable quantity of tip was turned brown or black, and was thus fendered invisible in a sample of tea. This does not occur to nearly the same extent in low firing. Experiments show that it is impossible to high fire tea at temperatures of 180°F or below, while at 200°F or over there is considerable danger of such an occurrence. The same remarks on first firing apply to second firing. Here the temperature should not exceed 180°F and the tea should come out fully dried. If a good 12-anna first fire is obtained, it will not be difficult to get a 15-anna second fire at 170-180°F.

It is important that after first firing the tea should go into the second machine as soon as possible. Tea lying in heaps, hot, and only partially dried, rapidly loses quality.

The use of automatic temperature recorders is strongly advised, and a deviation of not more than 5°F under ordinary conditions allowed. To deal with leaf of varying moisture content a variation in temperature of not more than 15°F should be sufficient in order that the tea may come out at a uniform degree of dryness.

"GAPING" OF TEA.

The practice of giving the tea a final fire after sorting and before packing to drive off any moisture accumulated during storage, is referred to in different districts as "gaping," "pucca-batti-ing" or final firing.

During the time that elapses between the second fire and packing, as much as 10 per cent. or 12 per cent. of moisture may be absorbed from the atmosphere of the factory. Tea keeps best with a moisture content of about six per cent. If tea contains more than this percentage, it "goes off," loses briskness and becomes flat. There is also risk of mouldiness. If tea is too dry it does not "mellow," but remains with a certain indefinable harshness peculiar to newly made tea. Thus gaping should aim at reducing the moisture content to five or six per cent. but not more. There is no point in gaping tea already at five per cent. moisture content. The apparatus for rapid determination of the moisture content in teas is cheap, and the process simple and capable of being carried out by the average clerk. It may be obtained from any Calcutta Chemical Dealers, at a cost of Rs. 200-250 and consists essentially of an oven, a weighing balance, a desiccator (drying jar) and some small basins. A quantity of tea is weighed into a basin and heated in a steam oven for a few hours. It is then cooled in the desiccator and weighed again. The loss in weight represents the moisture driven off, and calculated on a percentage

basis, is an indication of whether gaping is necessary, and if so, to what degree.

SORTING.

The sorting of tea is so largely dependent upon market conditions that it is not proposed to deal with it here. There is, however, one point to which attention might be called. The "greying" of tea may be brought about during sorting and cutting of the dry leaf and consists in rubbing and polishing the surface of the tea. Any machine therefore that causes a rubbing of the surface of the leaf tends to produce greyness. Machines running at high speed, by increasing the rubbing effect, tend to increase the amount of greyness. In sorting therefore the type of machine used should be one that, so far as is practicable, does away with the rubbing of the leaf. The circular sifters running slowly, consequently tend to grey the tea less than if they are speeded up, but in any case they cause the rubbing action to take place. Other machines such as rotary sieves running at much higher speeds also give greyness to the tea. Machines which produce a hopping rather than sliding action on the sieves tend to grey the tea less. Machines depending on an air-blast such as the deflector type of machine are the least liable to grey the teas. One cause for the greying of tea is the speed at which the cutters or breakers are run. A fast run machine will tend to grey the teas much more than one run slower, and consequently such machines should run at the slowest speed that is compatible with efficiency. One often sees such machines run at too high a speed in order to get through the amount of work, whereas what is really required is another machine so that the two machines may both work at proper speeds.

During sorting tip is very easily destroyed, consequently to obtain a tippy finished tea it is necessary that the fine mal should be subjected to the very least possible amount of sorting and cutting.

CUP AND LEAF QUALITY CHEMICAL ANALYSIS.

It is perhaps of interest here to explain some of the terms employed by tasters with regard to make of leaf and characteristics of liquors.

Leaf described as "irregular" means that the sample is a mixture of pieces of leaf of different sizes and shapes. The result is not a true grade and is sometimes referred to as "mixed." When a sample is termed "choppy," it is meant that the tea consists of, or contains, short straight pieces of leaf indicating too much cutting or chopping of the tea,

"Flakey" tea contains open untwisted pieces of leaf and results from a "kitcha" physical wither. Flakey tea due to under withering is often brown instead of black.

The appearance of big leaf is termed "bold" and may occur through bad rolling.

The best make of leaf is a black well twisted and even leaf. Tip should be golden, long, and well twisted in order that it may not shake down to the bottom of the blend.

A point which, perhaps more than any other, prejudices a buyer against a tea, is the appearance of an abnormal amount of dust. The demand for clean grades is always a strong one.

Although a stalky tea may give as good a liquor as one free from stalk, the latter always commands the best price, and as the refusal to buy stalky teas is almost universal, every effort must be made to exclude stalk.

With regard to liquors, many tasters employ different terms for the same characteristics, while one term often conveys different meanings to different tasters.

"Pungency" denotes the astringency or effect of a liquor on the membrane of the mouth. This is a "roughness," which affects the gums mainly.

"Briskness" can scarcely be described as a taste, but rather as an impression of "liveliness" similar to that of a new soda water as opposed with one which has gone flat.

"Point" refers to the presence of some outstanding characteristic. A tea lacking in point is called "empty," "washy," "weak," or "thin."

A "coloury" tea has dark reddish cup colour, but if this colour is more brownish, and the liquor, when hot, is not clear and bright, it is described as dull. Such a tea is seldom or never brisk or pungent.

"Strength" and "body" almost explain themselves and are understood by most planters. The amount of "creaming down" is often an indication of strength. A tea with strength often has a suggestion of "syrupiness," due to the high percentage of soluble solids present.

"Flavour" is the sweetish taste noticeable in early and late season teas, in particular Darjeeling and Ceylon teas.

The following is a typical chemical analysis of finished tea leaf.

	Percentage.
Water ... ..	... 11.49
Nitrogen compounds ... ..	... 21.22
Caffeine ... ..	... 1.35
Ethereal oil ... ..	... 0.67
Fat, wax, and green colouring matter ... ..	... 3.62
Gum and dextrin ... ..	... 7.13
Tannin ... ..	... 12.36
Other substances free from Nitrogen ... ..	... 16.75
Wood fibre ... ..	... 20.30
Ash (mineral salts) ... ..	... 5.11

100.00

When a tea is extracted for five minutes with boiling water, one-half to two-thirds of the total tannin and about $\frac{3}{4}$ of the

total caffeine dissolved out. The total amount of solid matter extracted is about 40 per cent. of the original weight of tea taken and half of this is extracted in a five minute infusion. This soluble solid matter, besides containing tannin and caffeine, contains gums, fats and protein matter, all of which go towards producing thickness of liquor. The more broken up the tea, the more easily are the substances extracted, and for this reason dust and fannings produce thicker liquors than the larger grades such as Pekoe and Orange Pekoe.

In addition to analysis of total tannin, two red substances formed in fermentation are estimated. One of these is thrown down from the infusion by addition of acid, while the other is thrown down by addition of salt to the infusion. Neither of these red substances is astringent, but the first is connected with the thickness of the liquor, and the second, with colour.

The table below gives analyses of various grades of the same tea, showing the tannin content of a one-hour infusion and a five minute infusion, and also caffeine, soluble solid content and moisture.

Grade.	% Tannin in 1 hour infusion.	Percentage in 5 min. infusion.			Moisture.
		Tannin.	Caffeine.	Soluble solid.	
Assam B. O. P. ...	10.78%	6.45%	0.80%	23.3%	7.15%
" P. F. ...	11.33%	7.55%	0.86%	24.0%	7.08%
" B. P. ...	10.45%	5.98%	0.85%	22.9%	6.55%
" B. P. S. ...	10.46%	5.99%	0.56%	21.2%	6.10%

Another analysis shows the percentages of the two kinds of tannin red in the tea.

Percentage in five-minute infusion.

	Tannin red insoluble in acid (thickness).	Tannin red insoluble in salt (colour).	Soluble Tannin (colourless & astringent).	Total.
Assam B. O. P. ...	2.14%	0.73%	4.69%	7.56%
" P. F. ...	2.67%	0.96%	4.60%	8.23%
" B. P. ...	2.07%	0.53%	4.35%	6.95%

Although the total tannin is greatest in the case of the Pekoe Fannings, the astringent tannin is not so great in comparison. There is a bigger percentage of the tannin-red substances, as one would expect from the appearance of the liquors, which are thicker and more coloury in the case of the P. F.

Although our chemical analysis is at present incomplete, it shows a considerable correlation with a taster's report and valuation except where a tea has outstanding flavour and is valued highly in consequence.

While chemical analysis can be a valuable aid in suggesting improvement in conditions of manufacture, it is never likely to supplant the present method of evaluating teas, open though the latter is to the inevitable personal errors of tasting.

SUMMARY OF IMPORTANT POINTS IN MANUFACTURE.

(1) The best tea is made from even leaf, containing no banjhi or hard leaf and consisting preferably of smallish shoots. Uneven leaf gives a poor uneven wither, the results of which cannot be corrected during later stages of manufacture. To obtain good leaf, fine plucking is essential.

The quality of shoot is improved by close plucking and bushes should be plucked as close as their condition will allow.

(2) Two withers must be recognised—the physical and the chemical.

A full chemical wither is necessary to the production of good teas. Methods for obtaining a good chemical wither, at the same time avoiding over physical withering, and sourness, are discussed.

(3) Hard rolling tends to give increased briskness, thickness, and strength of liquor, but increases red stalk. A good wither tends to lessen this production of red stalk by hard rolling.

Light rolling gives poorer liquors, but less stalk and better appearance unless the time of rolling is more than proportionately lengthened to allow for the fewer number of revolutions.

Fast and slow rolling have similar results to hard and light rolling respectively.

(4) Humid conditions in the fermenting room are necessary. The temperature of the fermenting leaf should not exceed 86°F at any time during fermentation.

Short fermentation gives brisk pungent liquors. Long fermentation gives thick soft liquors.

(5) The temperature for first firing should be 180°F, but leaf must be brought out 12 annas fired. Fan and tray speeds, and thickness of spreading must be regulated accordingly. The second fire should be 180°F and the tea should come out fifteen annas fired.

(6) Examination of infused leaf.

White tip and green colour means chemical underwither.

If bright green—"chemical and physical underwither."

If dull green, chemical underwither and physical overwither.

Dull brown infusion and soft liquors may mean chemical overwither.

Uneven colour of infused leaf means uneven withering.

Dull colours result from drying of fermenting leaf, owing to dry or draughty fermenting room.